Thesis/
Reports
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Spruce-Fir Research Cooperative: A Program Description

Spruce-Fir Research Cooperative
USDA Forest Service
Northeastern Forest Experiment Station
370 Reed Road
Broomall, PA 19008

SPRUCE - FIR RESEARCH COOPERATIVE: A PROGRAM DESCRIPTION

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370 Reed Road
Broomall, PA 19008

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(518) 442-3819

SPRUCE - FIR RESEARCH COOPERATIVE

The mission: To explain possible air pollution-related changes in the structure, function and composition of the forest ecosystem.

The Cooperative addresses two questions:

-- What are the effects of air pollutants and acid deposition, if any, on eastern spruce - fir forests?
-- Why are spruce declining at high elevations?

Scientists working within the Cooperative deal with the following Scientific Questions:

1.1 Are changes in growth and mortality and the presence of unusual foliar symptomology in red spruce - fir forests greater than can be attributed to typical trends and levels of natural variability?

1.2 What spatial patterns, if any, exist in growth and mortality and in the presence of unusual symptomology in red spruce - fir forests and how do these patterns relate to spatial patterns of pollutant exposure?

2.1 What is the effect of **sulfur** and/or **nitrogen** derived pollutants on red spruce and fir through (1) the mechanism of **direct toxicity** to **roots, mycorrhizae** or **soil microbial populations** by the mobilization of metals and (2) the mechanism of **leaching of nutrients** from the **rooting zone** by acid deposition resulting in altered tree water and nutrient balances?

2.2 What is the effect of **sulfur** and/or **nitrogen** derived pollutants alone or in combination with **oxidants** on red spruce and fir through the mechanism of **increased leaching** of **foliar nutrients**?

2.3 What is the effect of **sulfur** and/or **nitrogen** derived pollutants alone or in combination with **oxidants** on red spruce and fir **morphology** by the mechanism of **carbon allocation** and **physiological processes**?

2.4 What is the effect of **nitrogen** compounds alone or in combination with **oxidants** on red spruce and fir through the mechanism of increased **winter damage** due to **altered physiology**?

2.5 What is the effect of **sulfur** and/or **nitrogen** derived pollutants alone or in combination with **oxidants** on red spruce and fir through the mechanism of disrupting **reproduction** or **regeneration**? (Not being considered by The Spruce - Fir Research Cooperative)

2.6 What is the effect of **sulfur** and/or **nitrogen** derived pollutants alone or in combination with **oxidants** on red spruce and fir through the mechanism of **altered susceptibility to insects and pathogens**?

The Spruce - Fir Research Cooperative is just one component of a national effort called the Forest Response Program.

FOREST RESPONSE PROGRAM

The Forest Response Program (FRP) is a national, goal oriented research program.

Purpose: To provide information on how forests respond to airborne chemicals.

Sponsor: National Acid Precipitation Assessment Program

Funded by:

U.S. Environmental Protection Agency
U.S.D.A. Forest Service
National Council of the Paper Industry for Air and Stream Improvement (NCASI)
Coal Producers (Spruce - Fir Research Cooperative only):
AMAX Coal Company
Consolidated Coal Company
Peabody Coal Company

The program addresses three questions:

-- Is there a significant problem of forest damage in North America that could be caused by acidic deposition, alone, or in combination with other pollutants?
-- If so, what is the causal relationship between acidic deposition, alone, or in combination with other pollutants; and forest damage in North America?
-- If there is a causal relationship, what is the dose response relationship between acidic deposition, alone, or in combination with other pollutants; and forest damage in North America?

The Forest Response Program uses an interactive research process:

-- Epidemiological studies will be used to identify spatial or temporal patterns in forest conditions.
-- these patterns will suggest particular hypotheses to be tested in physiological or ecological studies.

Two research Support Groups, and four research Cooperatives conduct the research.

-- The Support Groups:
-National Vegetation Survey
-Atmospheric Exposure Cooperative

The Mountain Cloud Chemistry Program (MCCP), an extension of the Atmospheric Exposure Cooperative, is necessary to fulfill the objectives of the Spruce - Fir Program.

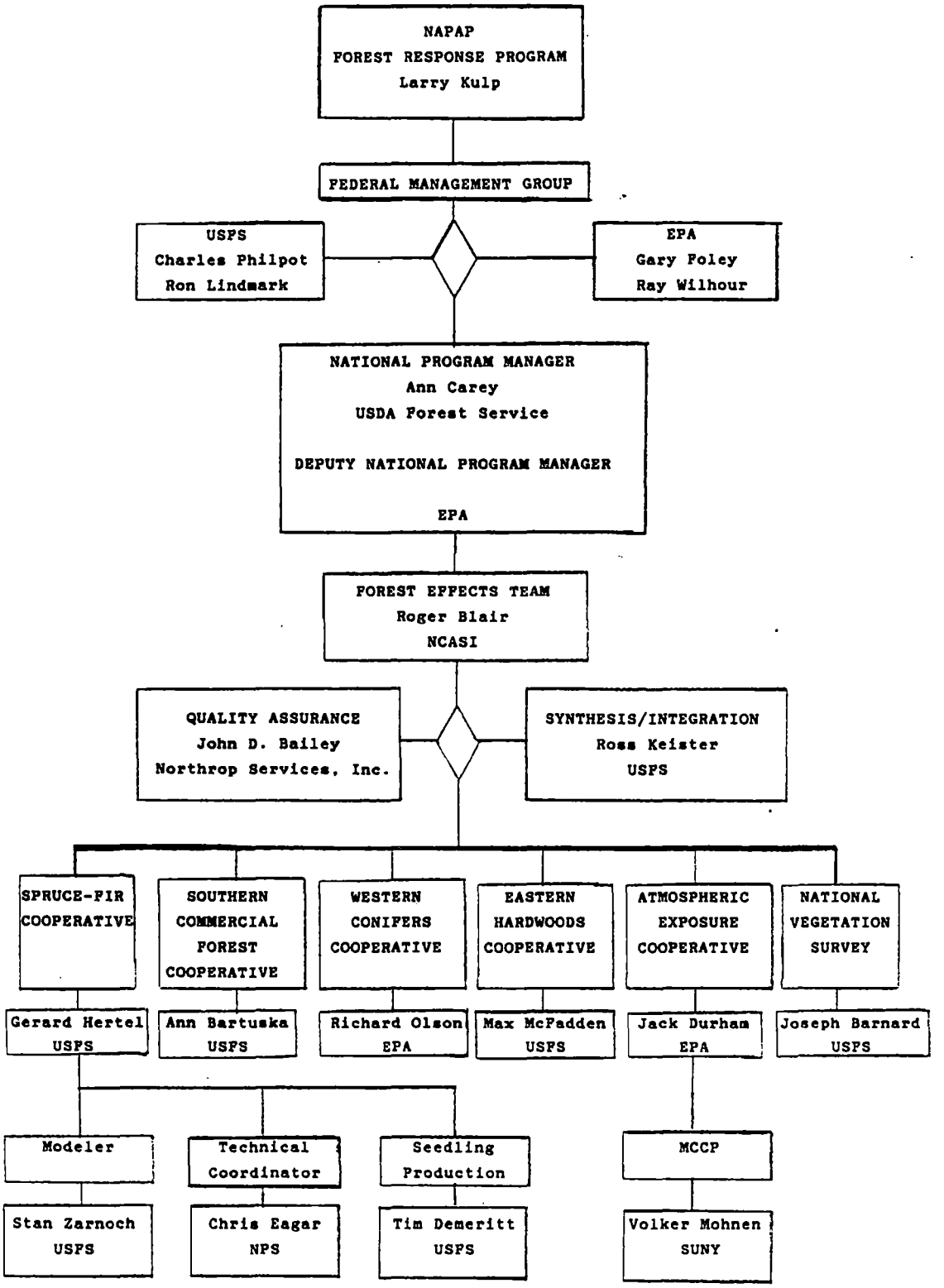
Purpose: To characterize the exposure of montane forested ecosystems to atmospheric inputs (chemical, physical, and climatic).

Objectives:
1. Determine the elevational gradients in wet and dry deposition.
2. Determine the relative significance of various deposition mechanisms to the fluxes of chemical materials into and through forest canopies.
3. Determine the frequency destributions of chemical, physical, and climatic exposure.

The research Cooperatives focus the research on four major forest types.

-- Spruce - Fir
-- Southern Commercial Pines
-- Eastern Hardwoods
-- Western Conifers

FOREST RESPONSE PROGRAM: MANAGEMENT FRAMEWORK



SPRUCE - FIR RESEARCH COMPONENTS

Thirty-five (35) funded projects currently address pertinent scientific questions.

1. Franklin T. Bonner (USDA Forest Service, SOFES). Quality of seed produced in declining Spruce - fir forests of the eastern United States.

2. Robert I. Bruck (North Carolina State University). Interactions of spruce - fir pathogens, insects and ectomycorrhizae on the etiology and epidemiology of boreal montane decline in the southern Appalachian Mountains.

3. Donald H. DeHayes (University of Vermont). Genetic Uniformity: A fundamental mechanism for red spruce decline.

4. Charles W. Dull (USDA Forest Service, Southern Region). Detection and evaluation of spruce - fir decline in the southern Appalachian using remote sensing. (completed)

5. Robert T. Eckert (University of New Hampshire). Genetic variation in red spruce pollution response.

6. Peter P. Feret (Virginia Polytechnic Institute and State University). The impact of environment and genotype on the reproductive fitness of Fraser fir from Mt. Rogers and Mt. Mitchell.

7. Ivan J. Fernandez (University of Maine). An integrated study of atmospheric deposition and nutrient cycling in commercial spruce - fir ecosystems.

8. Stewart M. Goltz (University of Maine). Management and environmental monitoring at Howland Maine.

9. Micheal Greenwood (University of Maine). Evaluation of the impact of atmospheric deposition on red spruce seedlings using open top chambers.

10. James F. Hornig (Dartmouth College). Studies of a spruce - fir forest at the Dartmouth-Mt. Moosilauke Research Forest.

11. Jay S. Jacobson (Boyce Thompson Institute). Test of the nitrogen fertilization hypothesis of red spruce decline.

12. Keith Jensen (USDA Forest Service, NEFES). Impact of ozone and acid deposition on foliar leaching and growth of red spruce seedlings.

13. Arthur Johnson (University of Pennsylvania). Quantifying spruce decline and associated forest characteristics at Whiteface Mountain, New York.

14. Arthur Johnson (University of Pennsylvania). The effects of acid precipitation on nutrient leaching, and metal mobilization on Whiteface Mountain, New York.

15. Siamak Khorram (North Carolina State University). Design and development of a base entry and management system for the Spruce - Fir Research Cooperative.

16. Robert J. Kohut (Boyce Thompson Institute). Comparison of the responses of seedling and sapling red spruce exposed to ozone and acidic precipitation under field conditions.

17. Lynn A. Maguire (Duke University). Experimental design and forest modeling for spruce - fir decline in the southern Appalachians.

18. Sandy McLaughlin (Oak Ridge National Laboratory). Interactive effects of natural and anthropogenic factors on growth and physiology of red spruce.

19. Stephen Mueller (Tennessee Valley Authority). Acid inputs to high elevation forest in the southeastern United States -- cloud contact, wet and dry deposition.

20. Bruce L. Parker (University of Vermont). The ghost moth, Hepialus gracilis, and red spruce decline.

21. Harvey L. Ragsdale (Emory University). Temporal patterns of tree diameter growth in southeastern high elevation Spruce - fir ecosystems (Completed).

22. Curtis Richardson (Duke University). Effects of atmospheric deposition on red spruce: A free radical-based approach.

23. Wayne P. Robarge (North Carolina State University). Quality assurance/quality control program for analysis of water, soil and plant samples.

24. John Seiler (Virginia Polytechnic Institute and State University). Impact of ozone and simulated acid rain on the growth, physiology and water relations of Fraser fir.

25. Dale Solomon (USDA Forest Service, NEFES). Modeling stand dynamics of spruce - fir forest in the northeast.

26. Frank Thornton (Tennessee Valley Authority). A field chamber study of the response of red spruce seedlings to cloud interception and /or ozone.

27. Michael H. Unsworth (Institute of Terrestrial Ecology, Scotland). Frost hardiness of red spruce in relation to forest decline and effects on red spruce of winter exposure to SO_2 and NO_2.

28. Philip M. Wargo (USDA Forest Service, NEFES). Relationship of root vitality to decline in spruce - fir forests in the northeastern United States.

29. Leonard Weinstein (Boyce Thompson Institute). Effect of ozone and soil nutrient status on the physiology of photosynthesis, carbohydrate allocation, nutrition, and winter hardiness in red spruce seedlings.

30. Carol G. Wells (USDA Forest Service, SEFES). Soil and plant tissue chemical properties associated with stand characteristics of spruce - fir in the southern Appalachians.

31. Carol G. Wells (USDA Forest Service, SEFES). Nitrogen transformation in soils of the spruce - fir ecosystems.

32. Thomas R. Wentworth (North Carolina State University). Compilation and interpretation of the vegetation data base and disturbance history of southern Appalachian spruce - fir.

33. Ronald C. Wilkinson (USDA Forest Service, NEFES). Geographic and genetic variation in foliar cuticle development and biochemistry of epicuticular waxes of red spruce (Picea rubens Sarg.) in relation to winter damage and decline.

34. Mansfield W. Williams (USDA Forest Service, NEFES). Mechanism of winter injury to red spruce foliage and possible complications resulting from supplemental inputs of nitrogen.

35. Shepard M. Zedaker (Virginia Polytechnic Institute and State University). Site and stand characteristics associated with potential decline and regeneration success of spruce - fir stands in the southern Appalachians.

Additional Spruce - Fir related projects funded by National Vegetation Survey:

1. Tommy R. Dell (USDA Forest Service, SOFES). A review of statistical methods for evaluation of atmospheric deposition influences on forests.

2. John R. Donnelly (University of Vermont). Heavy metal content of tree roots and stems: Lead mobility in the xylem of red spruce seedlings and its implications for use in producing pollution histories.

3. David B. Drummond (USDA Forest Service, Southern region). State-of-the-art report on the foliage symptoms of air pollution damage (project completed).

4. Charles W. Dull (USDA Forest Service, Southern Region). Pilot test of the application of geographic information system technology for monitoring boreal mountain forest decline.

5. James A. Hornbeck (USDA Forest Service, NEFES). Analysis and interpretation of tree cores in New England.

6. Richard Jagels (University of Maine). Analysis and interpretation of tree cores in New England: Fingerprinting radial increment data for red spruce using morphometric analysis.

7. Immants Millers (USDA Forest Service, Northeastern region). Cooperative survey on red spruce and balsam fir decline and mortality in the northeast: Symptoms and Trends.

8. Lewis F. Ohmann (USDA Forest Service, NCFES). Study the relationship between various aspects of forest conditions and atmospheric deposition across the northeastern Minnesota to southeastern Michigan deposition gradient.

9. Barrett N. Rock (Jet Propulsion Laboratory). Vegetation survey pilot study: Detection and quantification of forest decline damage using remote sensing techniques.

10. John M. Skelly (The Pennsylvania State University). A field investigation fo symptoms expressed by Norway spruce in Pennsylvania, West Virginia, New York, and New Hampshire--Are symptoms similar to those of "Waldsterben" in the Black Forest of Germany?

11. James D. Ward (USDA Forest Service, Southern region). Developing an aerial photographic technique for assessment of visual spruce - fir decline resulting from air pollution or other environmental stress in the southern Appalachians (completed).

Mountain Cloud Chemistry Program Projects:

1. Howland Experimental Forest (University of Maine; International Paper Company).

2. Mt. Moosilauke (Dartmouth College)

3. Whiteface Mountain (State University of New York - Albany)

4. Whitetop Mountain (Tennessee Valley Authority)

5. Mt. Mitchell (North Carolina State University)

Spruce - Fir Research Cooperative Projects

PRINCIPAL INVESTIGATOR	SCIENTIFIC QUESTION							
	1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6
Bonner, F.T.		*					*	
Bruck, R.I.	*	*						*
DeHayes, D.		*						
Dull, C.	*	*						
Eckert, R.T.		*						
Feret, P.		*					*	
Fernandez, I.			*	*				
Goltz, S.M.		*						
Greenwood, M.				*	*			
Hornig, J.	*	*						
Jacobson, J.				*	*	*		
Jensen, K.			*	*				*
Johnson, A.	*	*						
Johnson, A.			*					
Khorram, S.								
Kohut, R.					*			
Maguire, L.	*	*						
McLaughlin, S.					*	*		
Mueller, S.		*						
Parker, B.L.	*	*						*
Ragsdale, H.	*	*						
Richardson, C.					*			
Robarge, W.	*	*						

PRINCIPAL INVESTIGATOR	SCIENTIFIC QUESTION							
	1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6
Seiler, J.					*			
Solomon, D.	*	*						
Thornton, F.					*			
Unsworth, M.					*	*		
Wargo, P.	*	*						*
Weinstein, L.				*	*	*		
Wells, C./Binkley, D.	*	*	*					
Wells, C./Robarge, W.	*	*	*					
Wentworth, T.	*	*						
Wilkinson, R.						*		
Williams, M.W.						*		
Zedaker, S.	*	*						

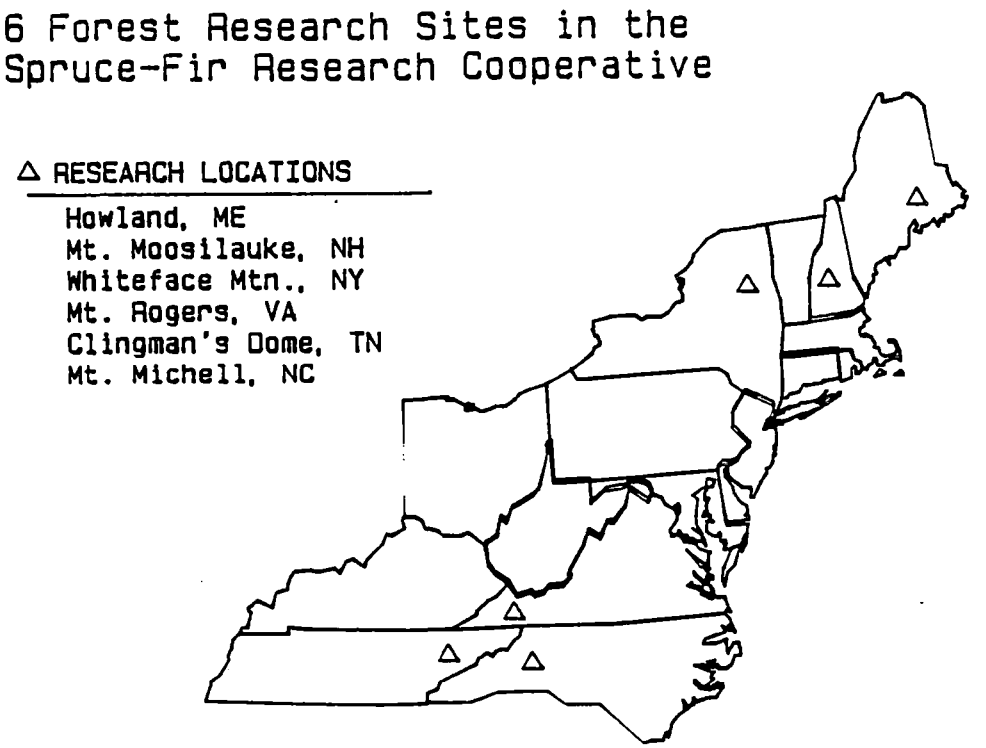
National Vegetation Survey Projects

PRINCIPAL INVESTIGATOR	SCIENTIFIC QUESTION							
	1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6
Dell, T.	*	*						
Donnelly, J.	*	*	*					
Drummond, D.	*	*						
Dull, C.	*	*						
Hornbeck, J.	*	*						
Jagels, R.	*	*						
Millers, I.	*	*						*

PRINCIPAL INVESTIGATOR	SCIENTIFIC QUESTION							
	1.1	1.2	2.1	2.2	2.3	2.4	2.5	2.6
Ohmann, L.	*	*						
Rock, B.	*	*						
Skelly, J.	*	*						*
Ward, J.	*	*						
Mountain Cloud Chemistry Projects								
All Research Locations	*	*						

PRIMARY RESEARCH SITES

	Sites	Site Control/Manager
1.	Northern Experiment Forest, Howland, ME	Thomas Saviello International Paper Co.
2.	Mt. Moosilauke, NH	James Hornig Dartmouth College
3.	Whiteface Mountain, NY	Volker Mohnen State University of New York
4.	Mt. Rogers, Whitetop Mountain, VA	Larry Grimes USDA Forest Service
5.	Clingman's Dome, Great Smoky Mountains, TN	Dave Mihalic National Park Service
6.	Mt. Mitchell, Clingman's Peak, NC	Tim McCree NC Department of Parks Bob Carey, USDA Forest Service



Technical Liaison Committee

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SARRMC:	Chris Eagar (615-436-7120) Uplands Field Research Laboratory Great Smoky Mtns. National Park Gatlinburg, TN 37738
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Research Institute:	Jay Jacobson (607-257-2030) Boyce Thompson Institute for Plant Research Tower Rd. Ithaca, NY 14853

RESEARCH COMPONENTS / SIGNIFICANT OUTPUTS

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE	RESPONSIBLE PI
Symptomology/ Growth/ Mortality Temporal (1.1)	Tree Cores	- Determine adequacy of tree core data bases and statistical techniques	2/87	Dell/Van Deusen (NVS) Hornbeck/Conkey (NVS)
		- Assemble "FORAST" on spruce - fir centralized data base	5/87	Khorram
	Permanent Plots	- Identify permanent plot data	4/87	Eagar, Peart, Siccama, Solomon
		- Assemble historical data base	5/87	Eagar, Khorram, Wentworth
		- Establish plots and assess change over time	12/88 and 12/90	
		- vegetation		Blum, Dull, Johnson, Peart, Zedaker
		- soils		Johnson, Robarge, Ryan, Wells
		- insects and diseases		Bruck, Knight, Parker, Smith, Wargo, Weidensaul, Weiss (NVS)
		- symptomatology		Johnson, Peart, Weiss (NVS), Zedaker
	Modeling	- Development of models to determine if there is a change from expected	3/89	Federer Maguire Mohnen (MCCP) Solomon, Weinstein (EPRI-ROPIS) Zarnoch
	Decision Criteria	----------		

* Changes greater than can be attributed to typical trends and levels of natural variability.

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE	RESPONSIBLE PI
Symptomology/ Growth/ Mortality Spatial (1.2)	Deposition Monitoring	- Gradients will be be determined.	12/86 cont'g	Mountain Cloud Chemistry Program
	Vegetation Monitoring	- Analysis of the Minnesota-Michigan gradient	12/87	Ohmann (NVS)
	Permanent Plots	- Establish plots and assess geographical variability	12/88 and 12/90	See Scientific Question 1.1
	Genetics	- An understanding of genetic uniformity and variation in red spruce and fir.		
		- Seed quality; healthy versus declining	6/88	Bonner
		- Reproductive fitness	6/88	Feret
		- Genetic variation in pollution response	11/88	Eckert
		- Genetic diversity and vigor	5/89	DeHayes
	Modeling	- Use of models to test patterns of forest condition	3/89	Maguire Solomon Weinstein (EPRI) Zarnoch
	Decision Criteria	---		

*Spatial patterns related to spatial patterns of pollutant exposure.

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE
2.1 (soils)	Controlled Lab	-NCASI literature review on Aluminum and Manganese	Completed
		-Dose/response of atmospheric deposition on Aluminum mobilization (EPRI-ALBIOS).	12/86
	Controlled Field	-Dose/response of acid precipitation on mature forests for soil pH, metal mobilization, and basic cations (Johnson; Watershed Manipulation Study).	12/88
	Uncontrolled Field	-Effect of atmospheric deposition on forest element cycling (Fernandez; EPRI-IFS)	12/89
	Decision Criteria	----------	
		*Effect of atmospheric deposition on metal mobilization and nutrient leaching.	2/90
	Controlled Lab	-Effect of Aluminum and Manganese versus Calcium on spruce root growth (McLaughlin)	9/87
2.2 (needle leaching)	Controlled Lab	-Dose/response of acid rain and O_3 on red spruce seedling throughfall (Jensen)	3/88
	Controlled Field	-Dose/response of O_3 on red spruce seedling cuticle morphology and foliage nutrients (Weinstein).	1/88
		-Dose/response of 3 acids and pH's in mist for leaching and foliar nutrients in red spruce seedlings (Jacobson).	3/89
	Uncontrolled Field	-Effect of acid deposition on foliar nutrients and cycling processes (Fernandez; EPRI-IFS & ROPIS)	4/89
	Decision Criteria	----------	
		*Effect of atmospheric deposition on foliar leaching.	6/89

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE
2.3 (carbon allocation)	Controlled Lab	-Exposure of red spruce to H_2O_2 (McLaughlin).	12/87
		-Dose/response of acid rain, O_3 and water stress on Fraser fir seedling growth parameters, gas exchange, and water potential (Seiler).	9/88
		-Dose/response of O_3 and acid precipitation on red spruce seedling development and physiology (Jensen)	9/88
		-Dose/response on studies on effects of wet and dry foliar deposited nitrogen on nitrogen metabolism, carbon allocation and growth (McLaughlin).	10/88
		-Dose/response of gaseous and wet deposition on red spruce seedling physiology and biochemistry (Unsworth)	1/89
	Controlled Field	-Describe repair and resistance mechanisms and metabolic expression of red spruce injury (Richardson).	11/87
		Dose/response of O_3 on red spruce seedling carbon allocation and photosynthesis (Weinstein).	1/88
		-Comparison of dose/response of 1 to 3 year old red spruce seedlings and saplings to 3 acids and 3 ozone treatments (Kohut).	9/88
		-Development of cloud exclusion chambers on mountains. Cloud water and O_3 effects on red spruce (Thornton).	12/88
		-Dose/response of 3 acids and pH's in mist on red spruce seedling growth, development, phenology, water relations, nutrient balance, and biochemistry (Jacobson)	3/89
		-Effects of ozone on the growth and morphology of red spruce and balsam fir; and the Effects of ozone, tissue maturation and water stress on red spruce (Greenwood)	12/91

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE
2.3 (continued)	Uncontrolled Field	-Field pilot study to characterize differences in gas exchanges, carbon allocation, and growth patterns across a gradient in decline and atmospheric deposition (McLaughlin).	10/88
	Decision Criteria	----------	
		*Effect of atmospheric deposition on morphology and physiological processes.	9/90
2.4 (winter injury)	Controlled Lab	-Effects of wet and dry foliar deposited nitrogen and seedling sensitivity to drought and low temperature stress (McLaughlin).	10/88
		-Effect of wet and dry deposition on red spruce frost hardiness (Unsworth).	1/89
	Controlled Field	-Dose/response of O_3 on red spruce seedling critical freezing point temperature (Weinstein).	1/88
		-Dose/response of N-fertilization on red spruce and balsam fir seedlings for foliar freezing injury and susceptibility to desiccation (Williams).	6/88
		-Dose/response of 3 acids and pH's in mist on red spruce seedlings freezing temperature and water relations (Jacobson).	3/89
	Uncontrolled Field	-Influence of needle anatomy and epicuticular waxes in relation to red spruce cuticular transpiration rates and winter injury (Wilkinson).	10/88
		-Time and rate of autumn frost hardening in relationship to red spruce frost injury (Unsworth).	1/89
	Decision Criteria	----------	
		*Effect of atmospheric deposition on susceptibility to winter freezing and desiccation.	2/90

SCIENTIFIC QUESTION	RESEARCH TYPE	OUTPUT	DUE DATE
2.5 (Reproduction)		-Not being considered by Spruce - Fir Research Cooperative	
2.6 (Insects & Diseases)	Literature Review	-Literature review (Bruck, Weiss)	5/86
	Sampling Methodology	-Sampling technique for ectomycorrhizae (Bruck).	6/88
		-Sampling technique for roots (Wargo).	12/87
	Field Surveys	-Surveys for insects and pathogens (Bruck, Weidensaul, Smith, Knight, Wargo, and Weiss)	1/88
	Decision Criteria	---	
		*Identify key insects and pathogens and their co-occurrence with decline symptomology.	1/88
	Controlled Lab	-Effect of ozone and acid rain on spruce budworm development (Jensen/Cannon)	9/88

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